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50 AH Nickel Cadmium Battery Activation and Charge Retention Parametric Study for Landsat-D

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ABSTRACT

An alternate nickel-cadmium cell activation scheme has been developed which significantly reduces battery dissipation while maintaining the cell active material in the proper electrochemical state. The new procedure of charging at C/20 for 8 hours, C/10 for 6 hours and followed by C/5 to a voltage limit of 1.430 volt/cell significantly reduces the heat dissipation and charge period when compared to the standard activation practice of charging at C/20 for 48 hours. In addition, subsequent discharge voltage profiles using the new scheme are higher when compared to the standard practice.

The effects of extended open-circuit periods on nickel-cadmium cell results in a capacity loss of approximately 0.7% and 1.4% per day at 23 and 35 degrees Celsius, respectively.

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ACKNOWLEDGEMENTS

The author acknowledges the support and suggestions of Mr. G. Halpert, Space Power Applications Branch, Goddard Space Flight Center who was first to recognize the need for an alternate battery activation procedure, conceived the idea and plan on which this work is based. The author also acknowledges Mr. S. Tiller, Space Power Applications Branch, for his support in organizing the test and providing the software to perform the test program.

50 AH NICKEL CADMIUM BATTERY ACTIVATION AND CHARGE RETENTION PARAMETRIC STUDY FOR LANDSAT-D

INTRODUCTION

The launch of Landsat-D scheduled for 1982 is the first Multi-Mission Spacecraft (MMS) on which the NASA 50 AH battery will be used. Because nickel-cadmium technology is being extended from NASA experience with the 20AH cell design, special considerations must be given to operating and maintaining the battery in the proper condition with a minimum of heat generation and degradation. Two specific areas covered by this report are battery activation and open-circuit periods at elevated temperatures.

During spacecraft integration, nickel-cadmium batteries are subjected to an electrical activation. The purpose is to maintain the cell's active material in the proper state and to restore the discharge voltage characteristics lost due to cycling or inactivity. The standard method of nickel-cadmium activation, which consists of a complete cell/battery discharge and resistive letdown to zero volts followed by a low rate C/20* recharge to a total input capacity of 250% of its rated battery capacity, is impractical for Landsat-D. For Landsat-D with three 50 AH batteries, this charge scheme results in approximately 225 watts dissipation during the final 15 hours which greatly exceeds the Modular Power Subsystem's (MPS) thermal control capability. An alternate activation procedure must be developed which minimizes heating yet properly conditions the battery.

Prior to launch, the MMS/MPS batteries experience a capacity and voltage loss during periods of open-circuit stand at elevated temperatures. Characterizing the self-discharge rate is particularily important during a shuttle launched MMS where prelaunch activities require extensive periods of battery inactivity.

* The term "C" is defined as the manufacturer's rated capacity and will be used to describe the current for either charging or discharging the battery.

OBJECTIVES

The objectives of the test program are to develop an alternate battery activation charge procedure which reduces the charge time and overcharge battery dissipation and to determine the effect of extended open-circuit stand at elevated temperatures on battery performance.

METHODOLOGY

A parametric test program was developed using two identical 50 AH five cell packs and subjecting the packs to a series of activation cycles followed by a capacity discharge. One pack, identified as the control, was subjected to the standard activation charge and discharge. The pack was then fully recharged using the NASA/GSFC voltage vs temperature (VT) limit of level 6 followed by a discharge to establish a baseline capacity measurement. The second pack was used to test and evaluate various alternate activation charge schemes followed by the same VT recharge and discharge. The charge and discharge voltage characteristics and discharge ampere-hour capacity was used to compare pack performance during each test condition.

For the purpose of determining the charge retention characteristics, the packs were activated and remained on open circuit at 23 and 35°C prior to discharging.

1.0 Test Results and Discussion

1.1 Alternate Activation Study

Prior to initiating the test program, a series of baseline activation and capacity tests were performed on the two packs. This electrical activation consisted of charging at the C/20 rate for 48 hours followed by C/2 discharge until the pack voltage dropped to 1.0 volt per cell. The packs were then recharged at C/10 for 16 hours and discharged. The last test consisted of recharging at the C/2 rate to the NASA/GSFC standard temperature vs voltage limit (VL) level 6 or 1.428 volts/cell (Figure 1). When the pack reached the preset voltage limit, the current was

allowed to taper with the charge terminated at C/20. The discharge was again repeated at the C/2 rate. The test temperature during all tests was 24° ± 2°C. The initial test results which appear in Figure 3 indicate that pack capacities, individual activation and VL discharge profiles were identical.

The test matrix consisted of subjecting the control pack to three consecutive standard activation charges followed by a voltage limit (VL) recharge and discharge. The test pack underwent four activation variations followed by the same VL recharge and capacity determination. After each series of tests, the packs were letdown and shorted for a minimum of 160 hours before attempting another activation cycle.

The results of the first three activation and VL capacity discharges for the control pack are shown in Figures 4 and 5. The discharge profiles remain similar with a slight loss in capacity with subsequent trials. The results of the test pack which underwent three alternate activation schemes are shown in Figures 6 and 7. The standard procedure is shown for comparison. The discharge profiles using the charge scheme of C/20 for 8 hours, C/10 for 6 hours followed by C/5 to voltage limit level 6 until the current tapers to C/20 was approximately 5 to 10 millivolts per cell higher than the other schemes. Further analysis revealed that the discharge ampere-hour and watt-hour capacities are identical.

In order to verify these results, the control pack was subjected to additional trials. Those results which appear in Figure 8 and 9 confirm the results of the test pack. A comparison of cell parameters for the standard activation charge and the alternate scheme of C/20 for 8 hours, C/10 for 6 hours, and C/5 to VL6 with an end-of-charge current of C/20 is shown in Figure 10 and 11. The cell pack was maintained at the test temperature of 23°C with the aid of chamber and baseplate cooling during the standard activation charge. The alternate scheme was performed without any thermal cooling. The pack temperatures remained at ambient temperature throughout the entire charge period.

1.2 Charge Retention Characterization

The final test results appear in Table 1 and Figure 12. The packs were activated using the standard procedure prior to the start of the test program.

Table 1

Charge Retention Test Results

Trial	1st OC Temp (°C)	1st OC Period	2nd OC Temp (°C)	2nd OC Period	Discharge Capacity Loss (%)
1	35	6 hrs	23	20 hrs	0.8
2	35	6 hrs	23	70 hrs	3.1
3	23	35 days	—	—	24.5
4	35	30 days	—	—	42.8

In addition to determining the charge retention characteristics, the packs were recharged after an open-circuit period and then discharged to verify the adequacy of the flight support equipment to recharge the batteries. The open-circuit period selected was 7 days at 23°C. The recharge was accomplished at C/5 to VL5 until the end-of-charge current tapered to C/20. The recharge period was approximately 45 minutes. The pack was discharged at the C/2 rate and delivered full capacity.

CONCLUSIONS

A nickel-cadmium activation scheme that significantly reduces battery dissipation while conditioning to a higher activation state has been tested and found to be superior to the standard activation procedures.

The new scheme consists of charging at the C/20 rate for 8 hours, C/10 for 6 hours followed by C/5 to the voltage temperature level 6 (1.428 volts/cell) until the end-of-charge current tapers

to C/20. These constant current rates together with the voltage limit charging are compatible with the Module Power Subsystem and battery power conditioning equipment.

The effect of open-circuit stand on capacity degradation at elevated temperatures indicates a capacity loss of 0.7% and 1.4% per day at 23 and 35 degrees Celsius, respectively.

APPENDIX A

Cell and Pack Design

The 50 AH nickel-cadmium cells were procurred from General Electric under NAS-5-23844. These cells from lot 1 are identical to the cells which completed initial evaluation tests and are currently undergoing life cycle tests at NWSC, Crane, Ind. (reference 1). Two identical 5 cell packs were constructed using 1/4" thick aluminum restraining plates, mounted on a thermal cooling plate and installed in separate temperature chambers. Each pack consists of five series connected cells containing one third electrode cell and one fitted with an electronic pressure transducer. The third electrode load resistor is 200 ohms. Specific cell design features appear in reference 1. The 50 AH five cell pack is shown in Figure 2.

REFERENCES

1. Initial Evaluation Tests of GE 50 AH nickel-cadmium spacecraft cells for the Landsat-D satellite program, WQEC/C 80-104, dtd 9 Apr. 1980, Naval Weapons Support Center, Crane, Indiana.

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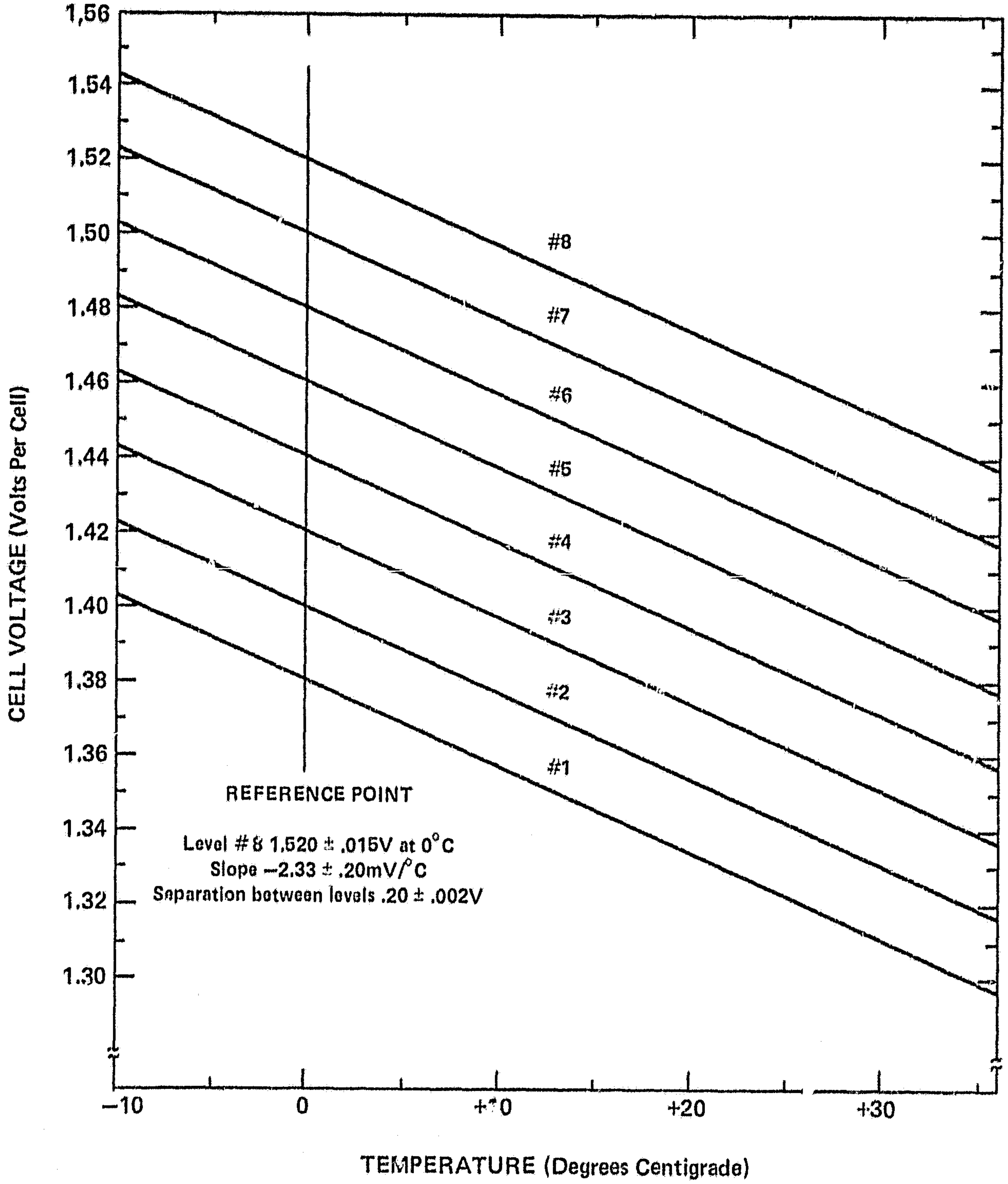

Figure 1. Voltage/Temperature Characteristics for Multilevel Nickel Cadmium Battery Charging

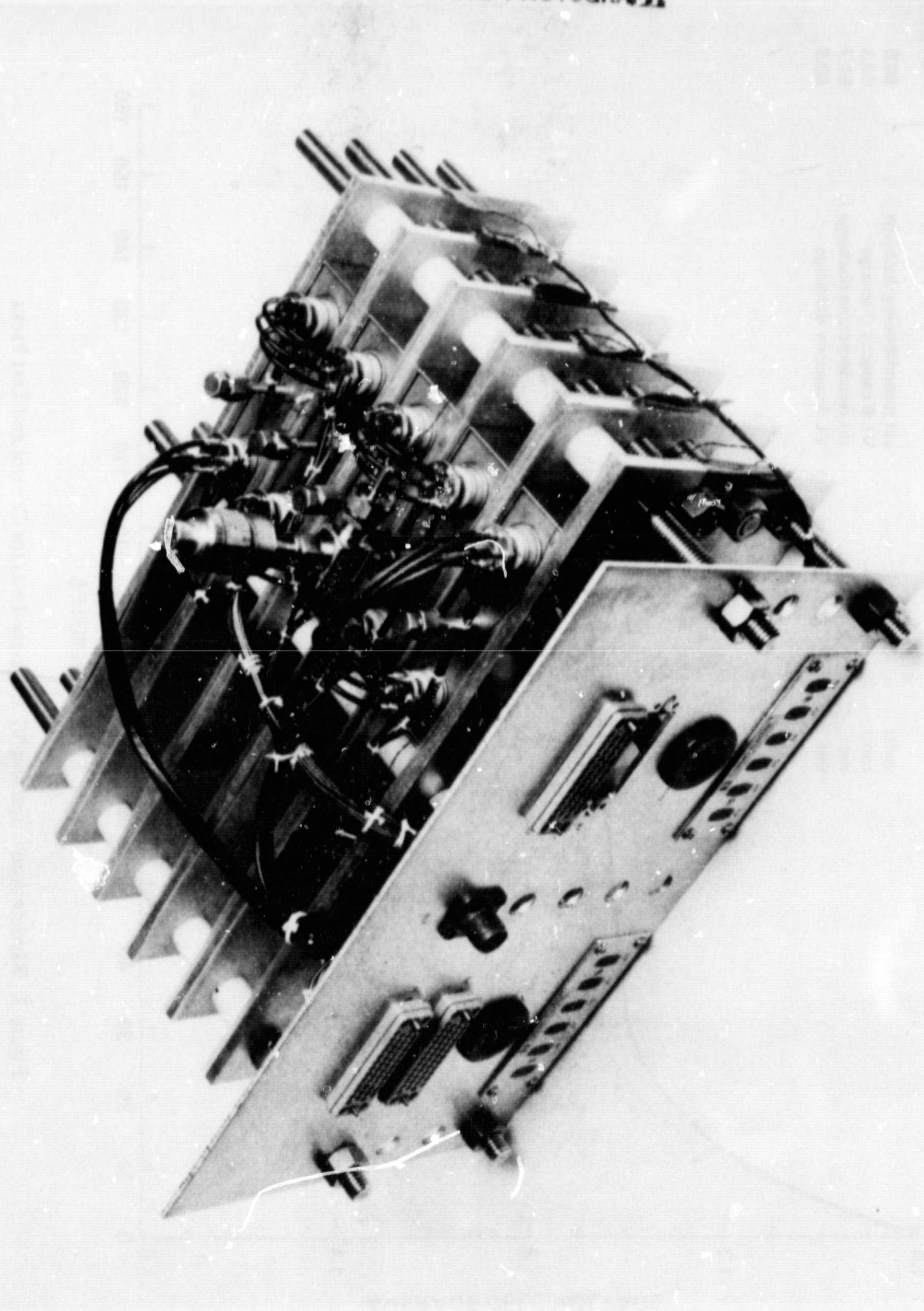

Figure 2. 50 AH 5 Cell Pack

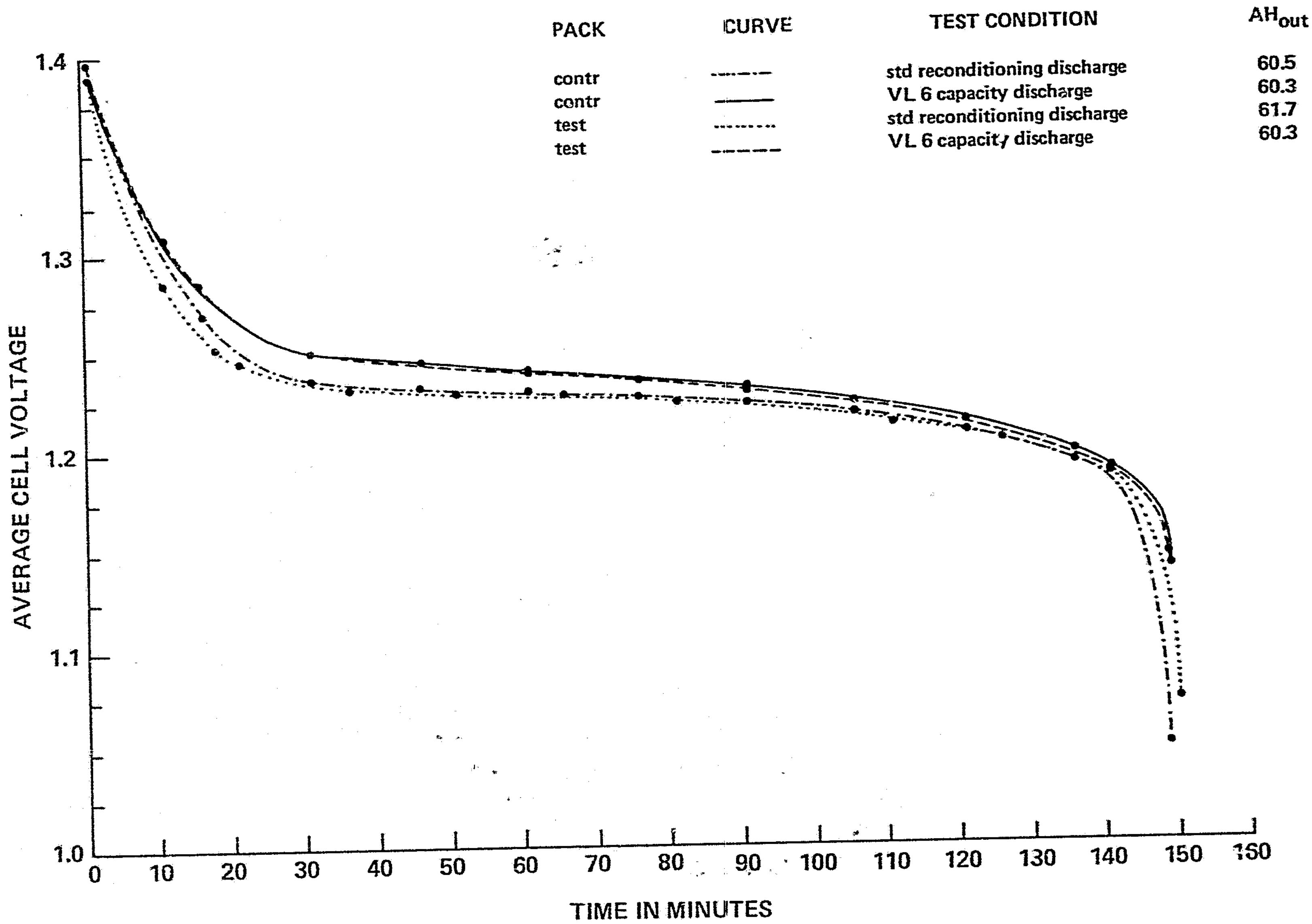

Figure 3. Baseline Activation and VL Capacity Tests for Control and Test Packs

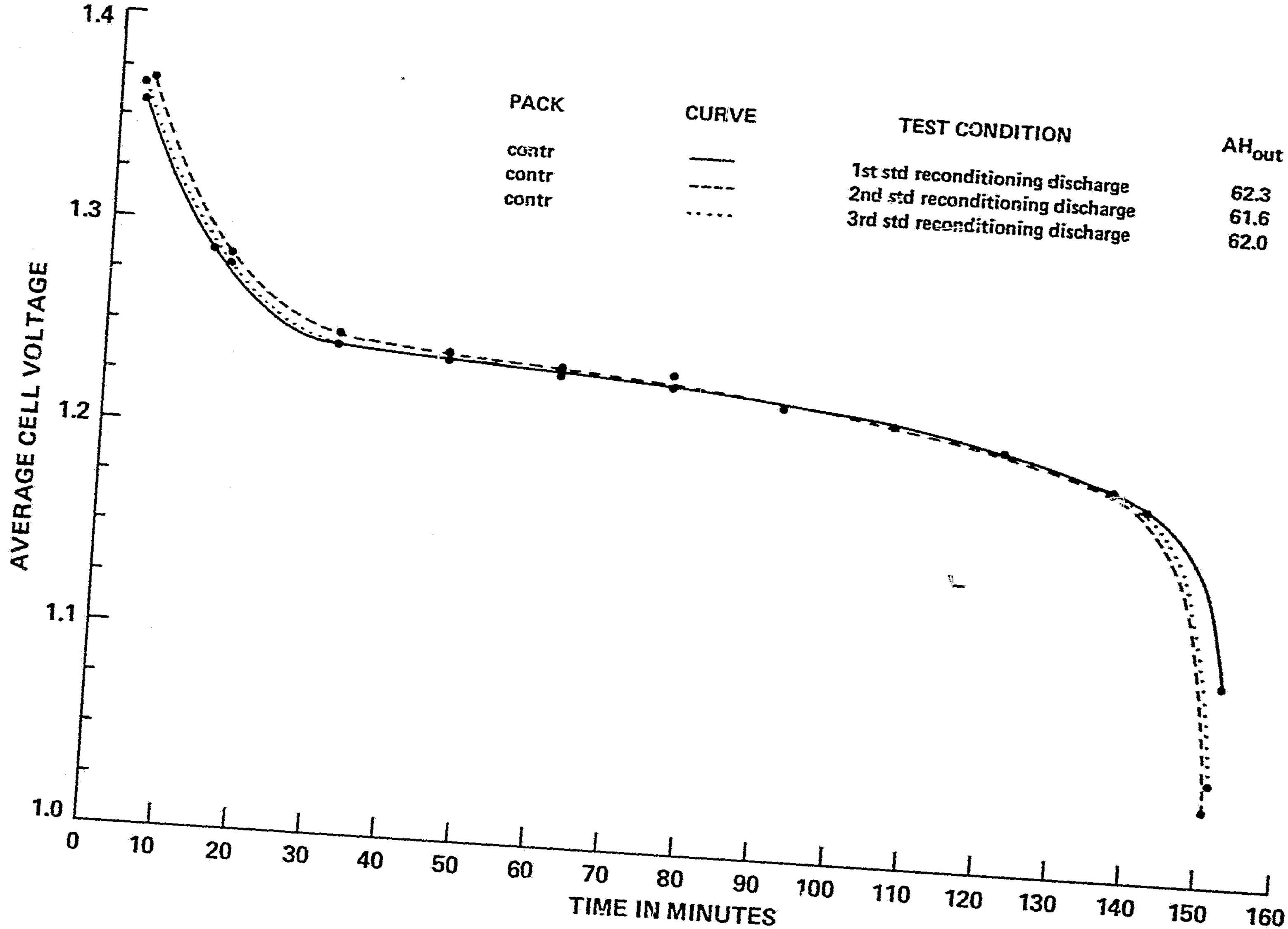

Figure 4. Control Pack Standard Activation Capacity Discharge

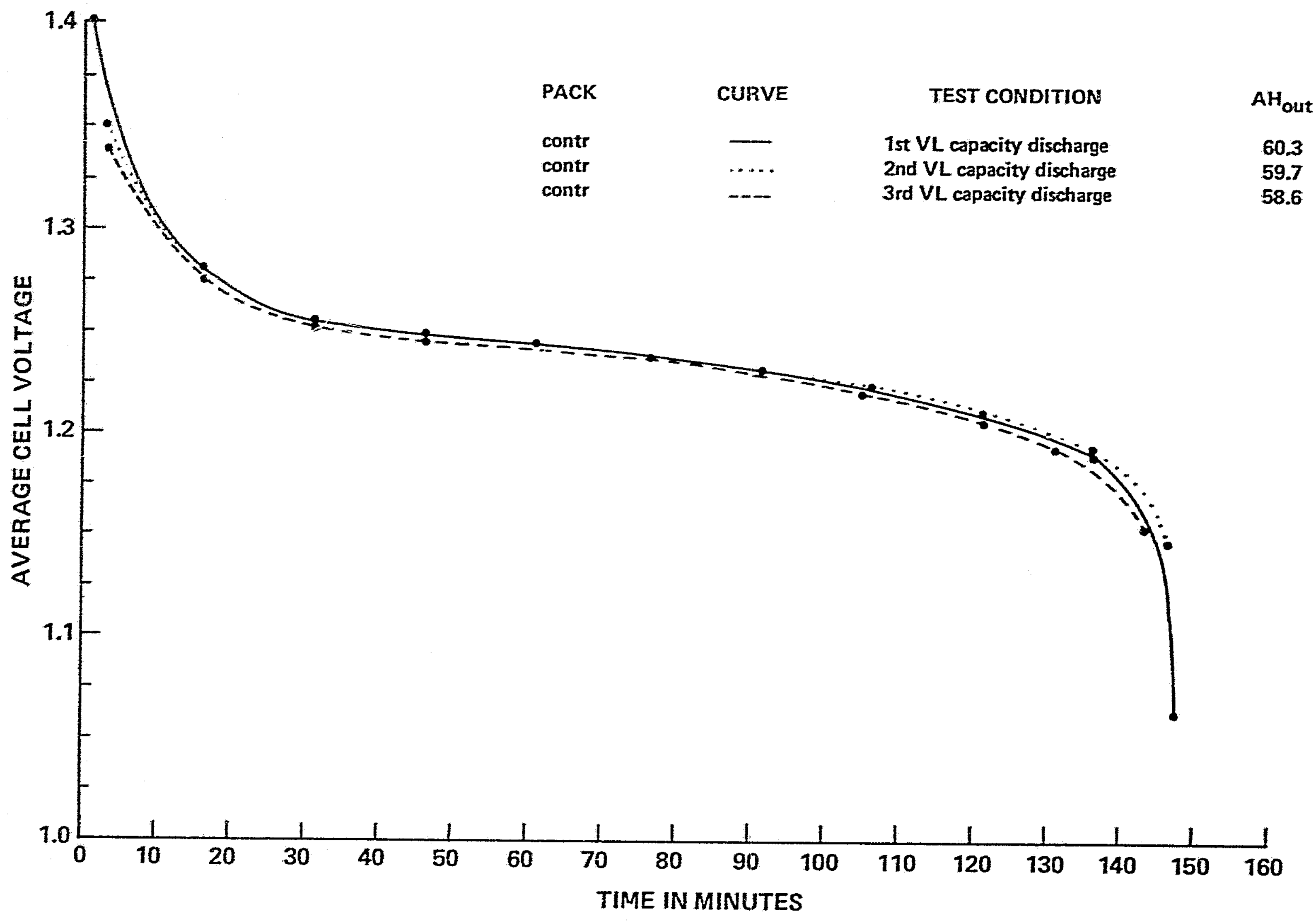

Figure 5. Control Pack Voltage Limit Capacity Discharge

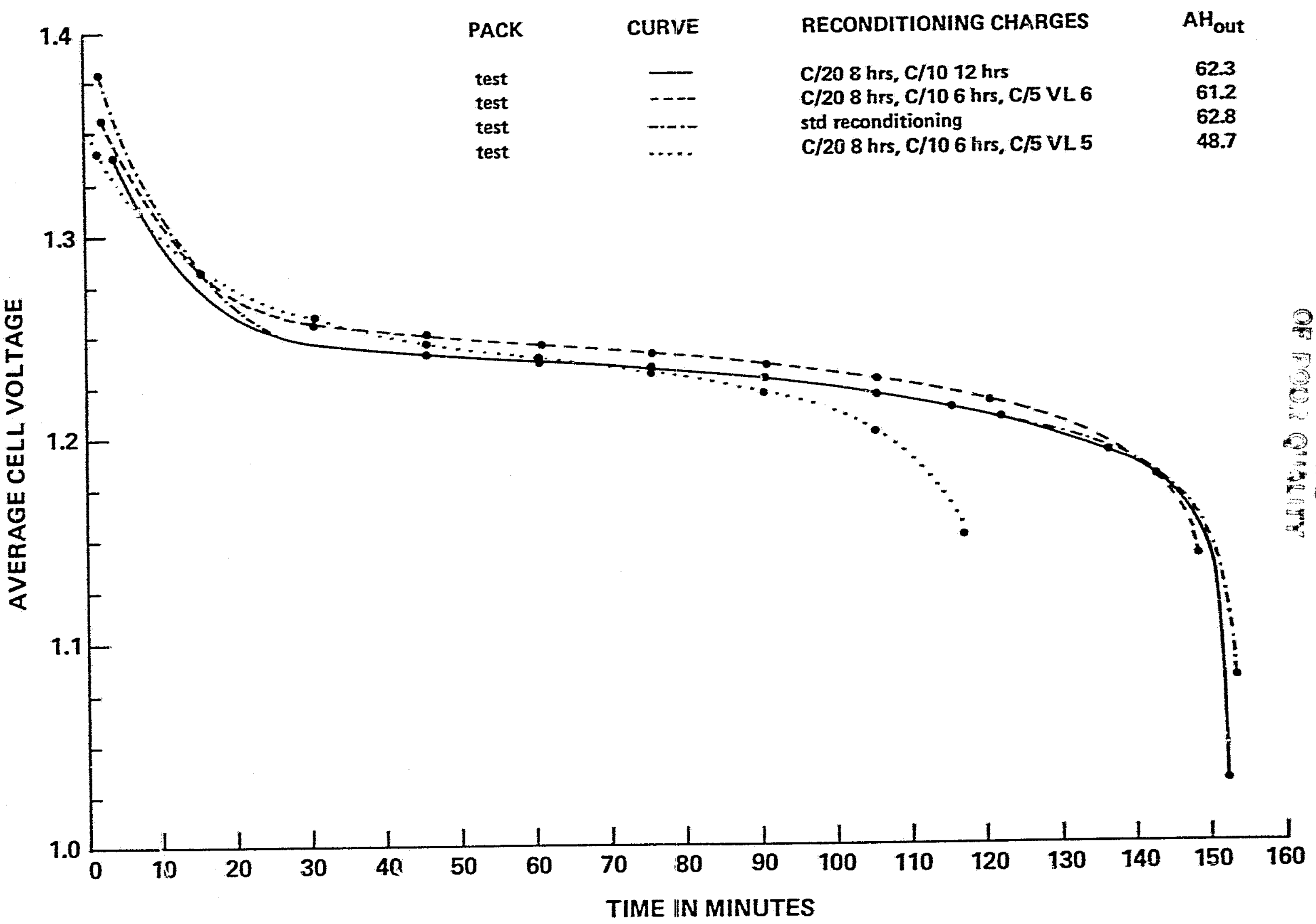

Figure 6. Test Pack Activation Capacity Discharge Comparison

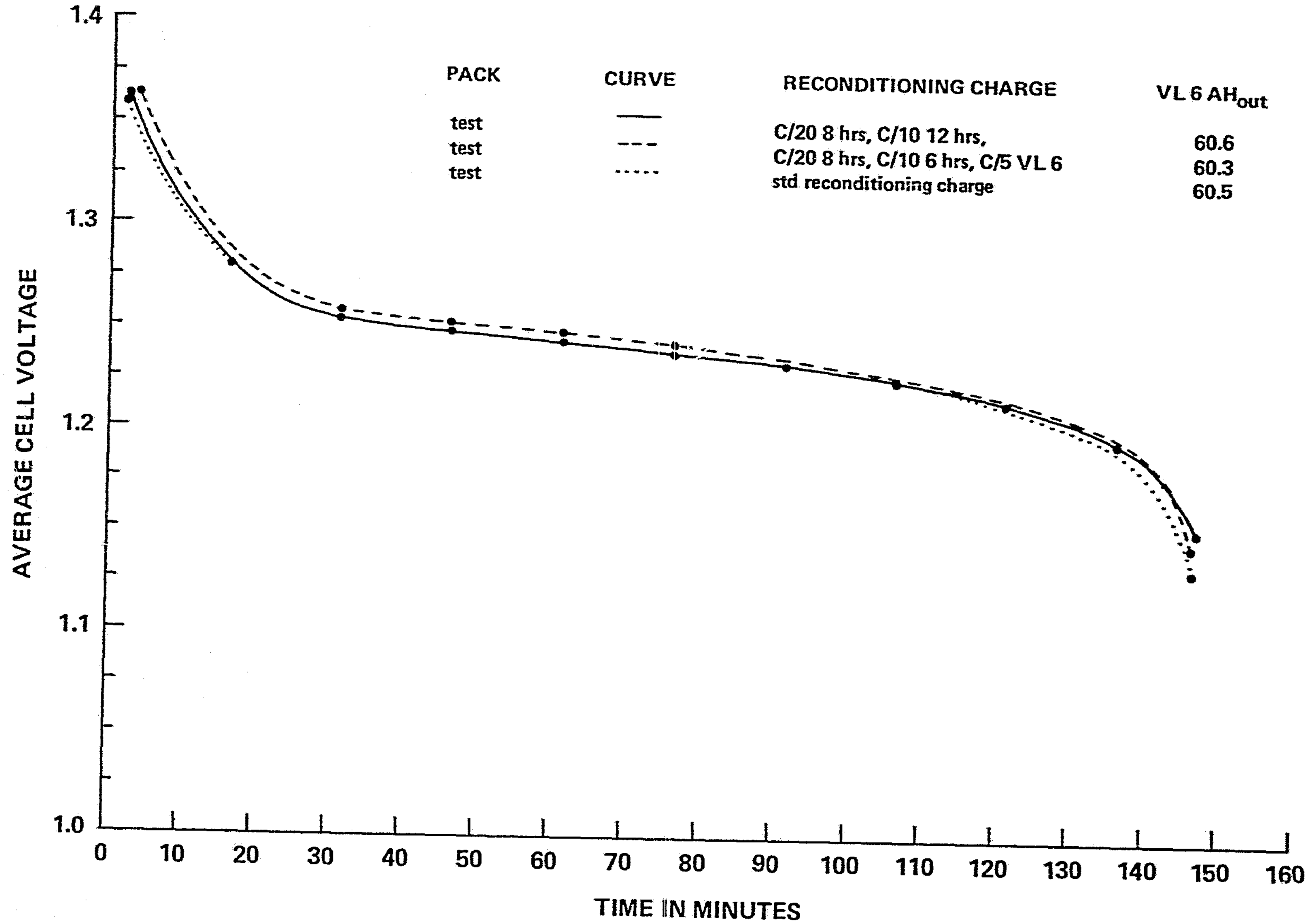

Figure 7. Test Pack Voltage Limit Capacity Discharge Comparison

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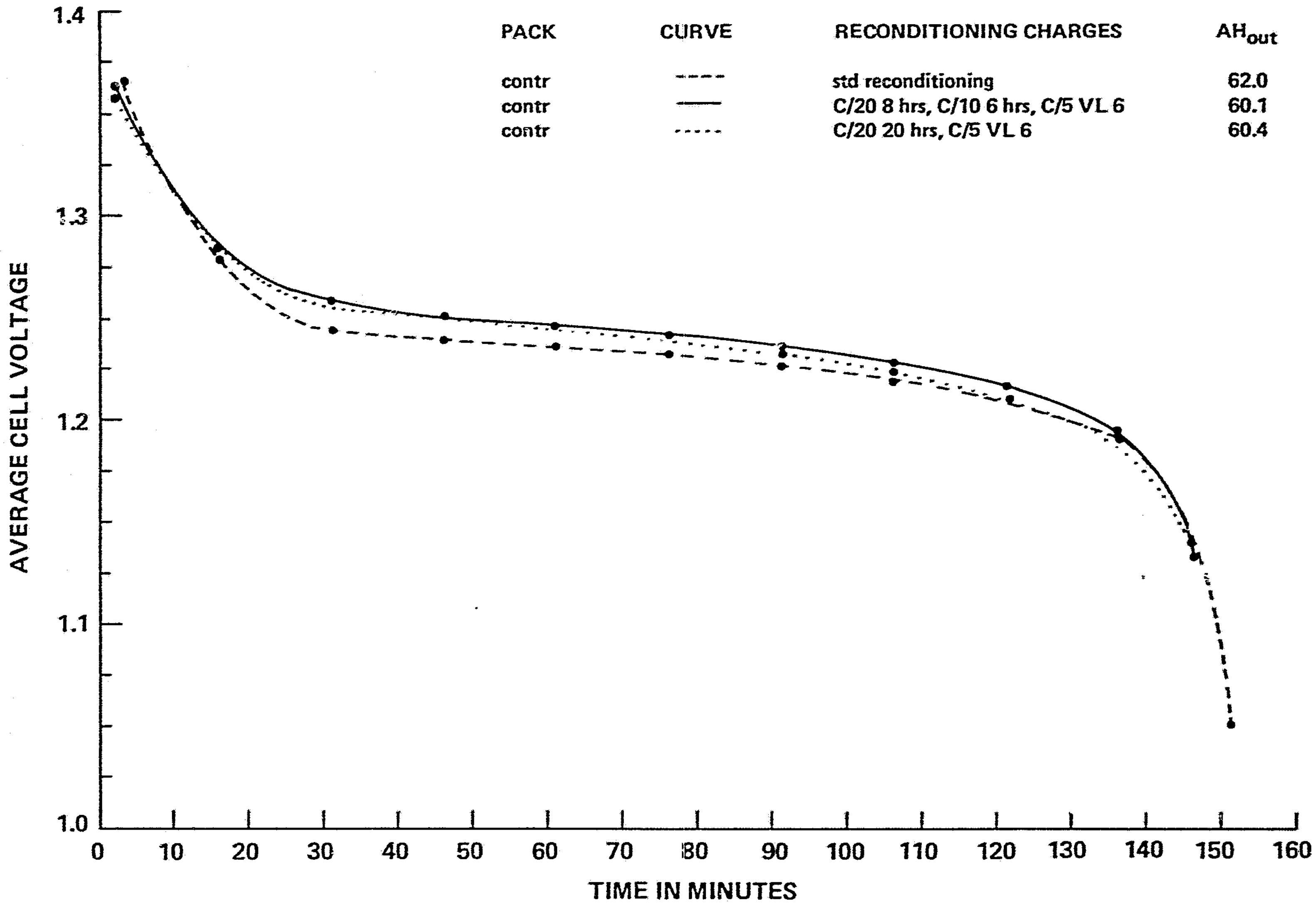

Figure 8. Control Pack Activation Capacity Discharge Comparison

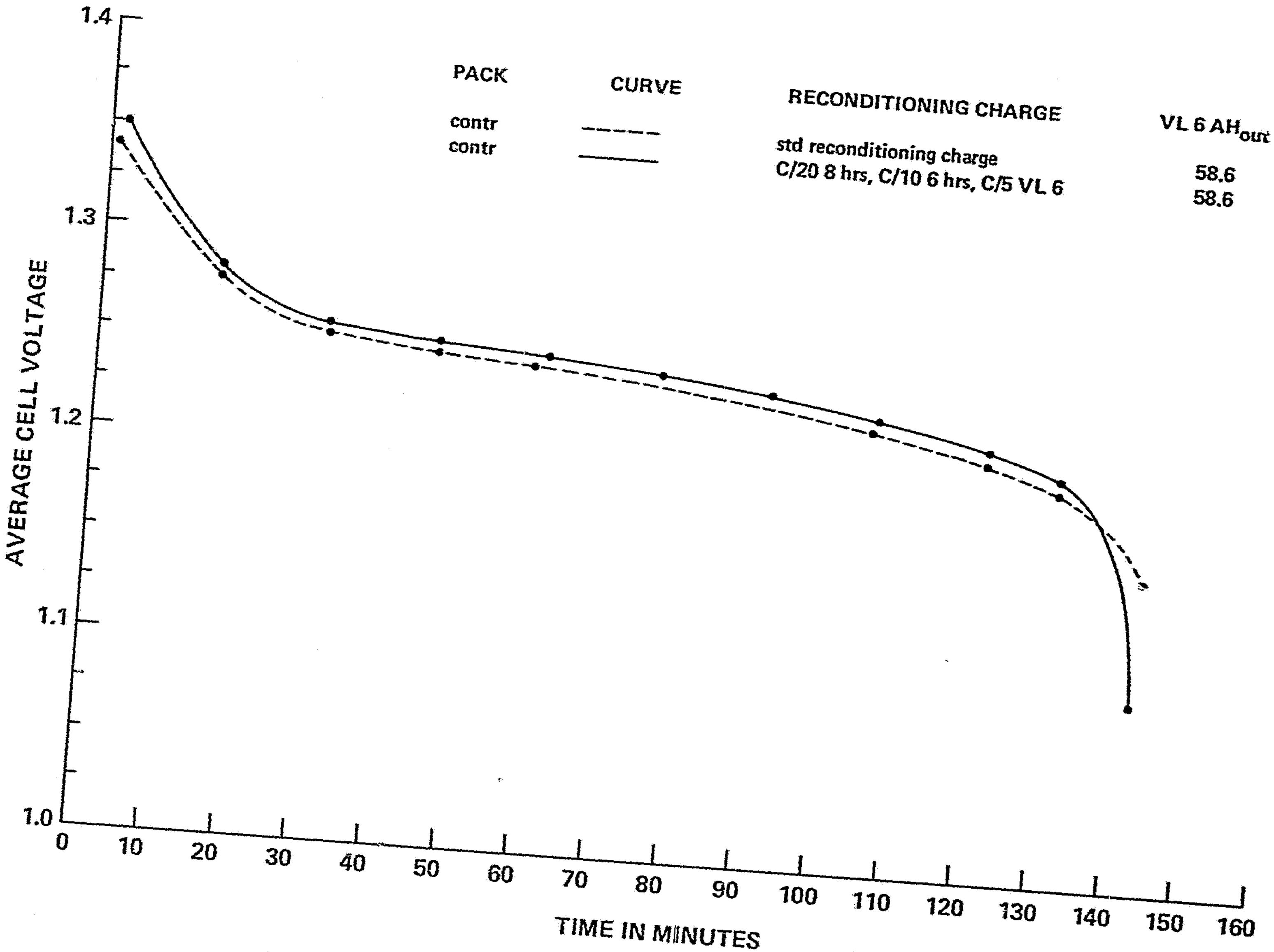

Figure 9. Control Pack Voltage Limit Capacity Discharge Comparison

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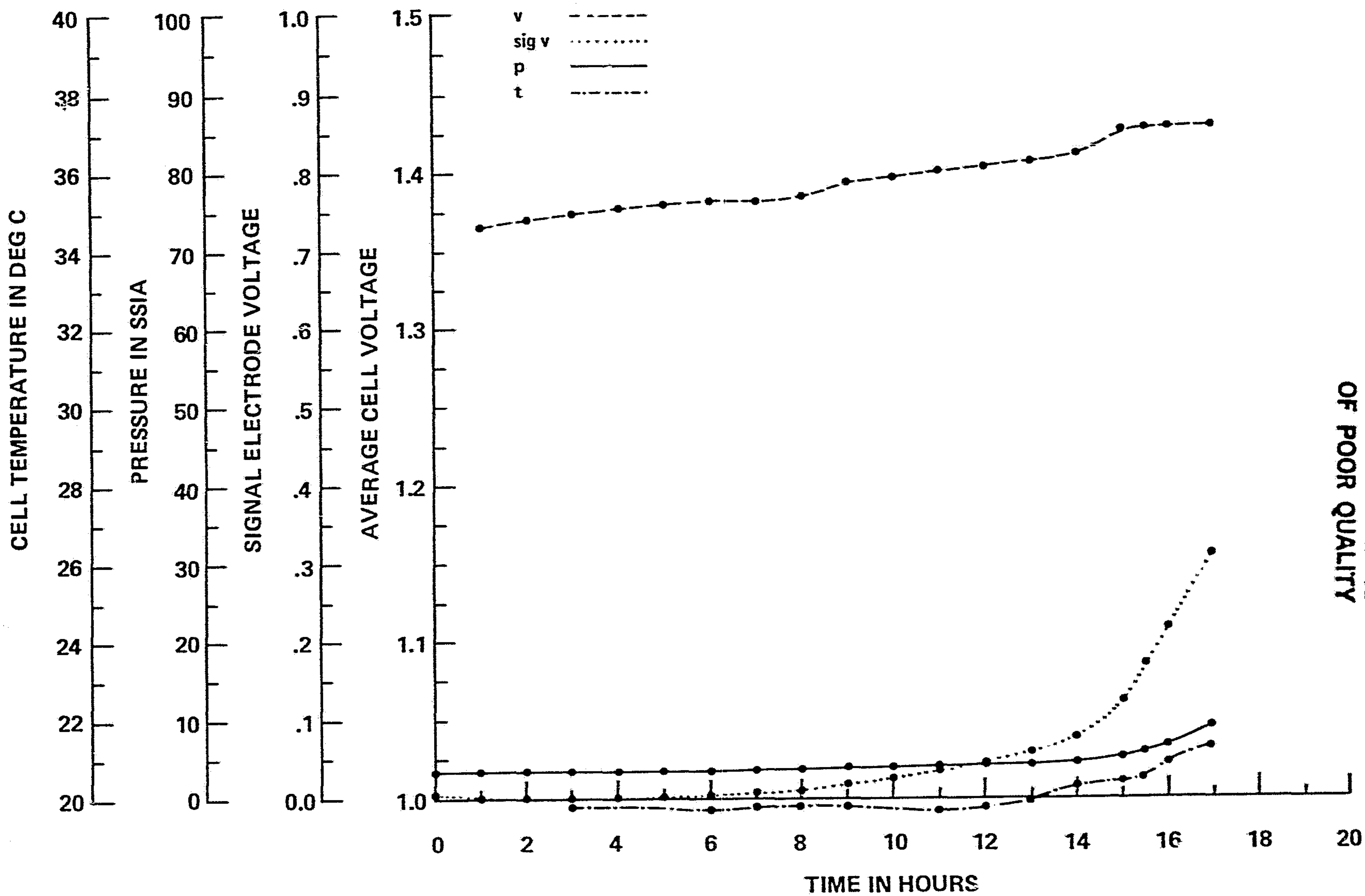

Figure 10. Control Pack Activation Charge Characteristics for C/20 for 8 hours, C/10 for 6 hours and C/5 to Voltage Limit Level 6 and C/20 EOCI

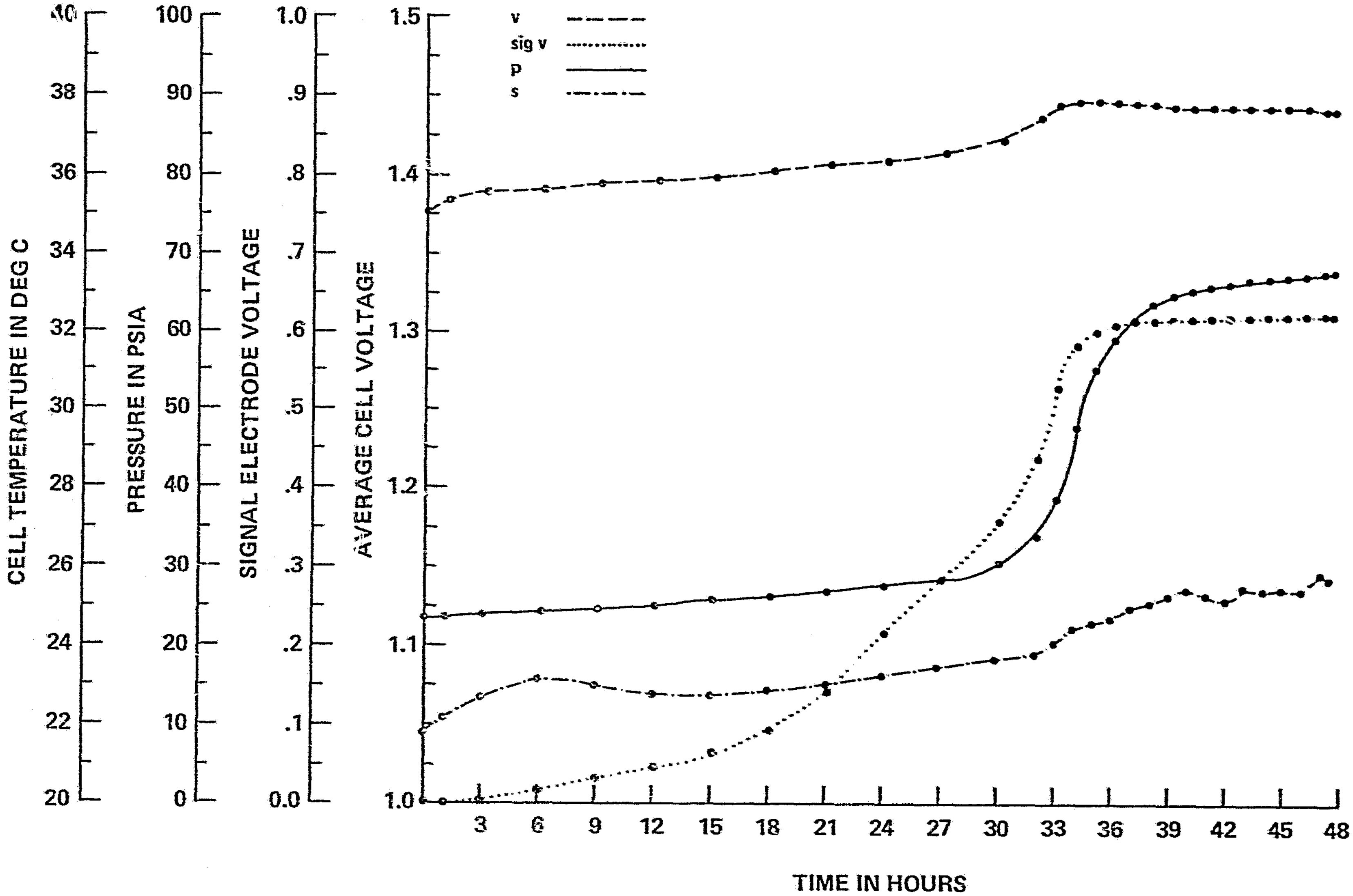

Figure 11. Control Pack Standard Activation Charge Characteristics, C/20 for 48 hours

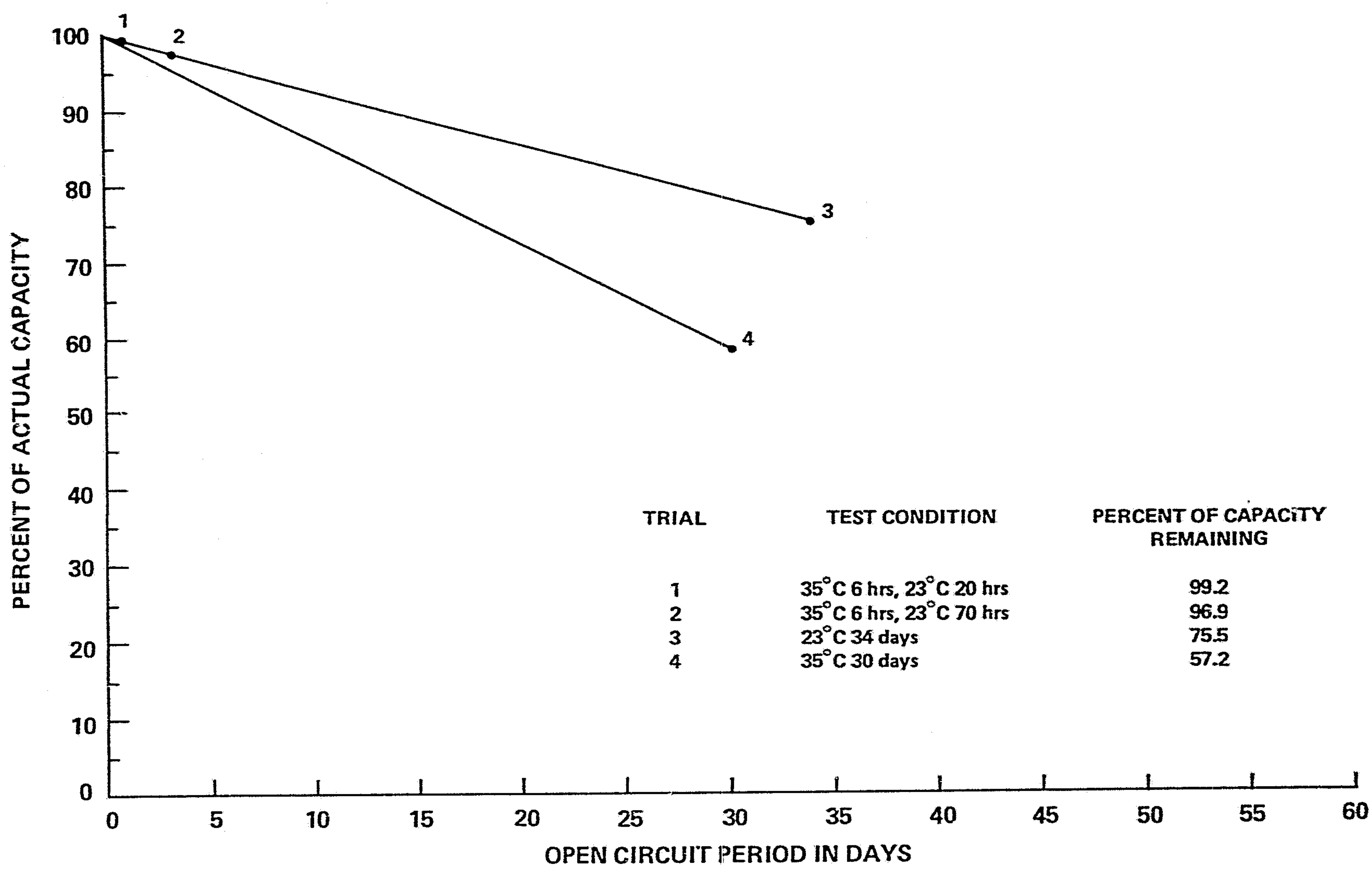

Figure 12. Charge Retention Characteristics